

Divergent sub-Neptune populations revealed by host star properties

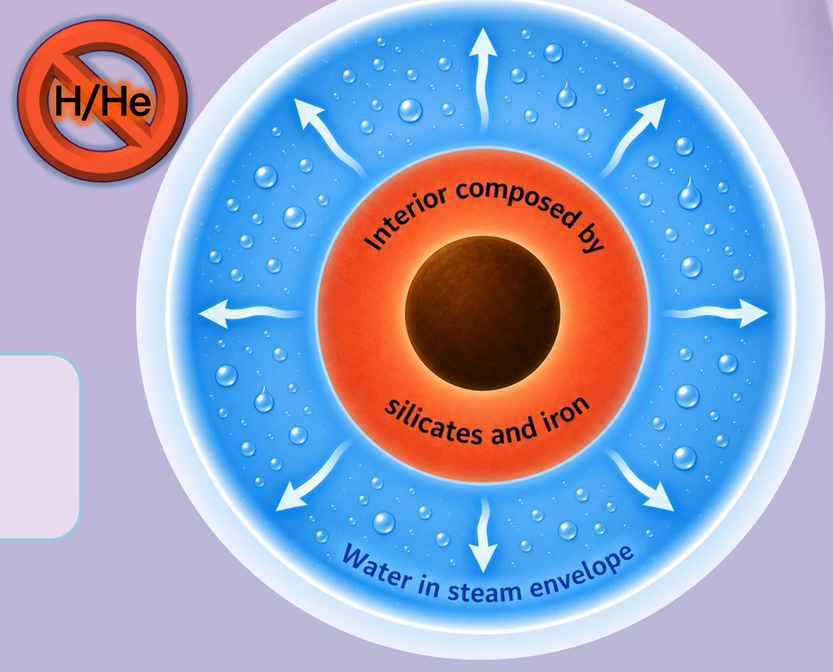
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Our starting point

The **radius valley** is a known region with a lack of planets in the bimodal planetary radius distribution. This gap separates super-Earths from sub-Neptunes. Previous studies suggest that **sub-Neptunes that lose their atmosphere turn into super-Earths**. This loss can happen due to **photoevaporation** or **core-powered mass loss**. Analytical works predict a **correlation between R_{planet} and $[Fe/H]_{star}$** for sub-Neptunes and an **absence** of it for super-Earths
→ contradictory results: some observational works confirm the correlation, but others cannot find it.

Separating super-Earths and sub-Neptunes

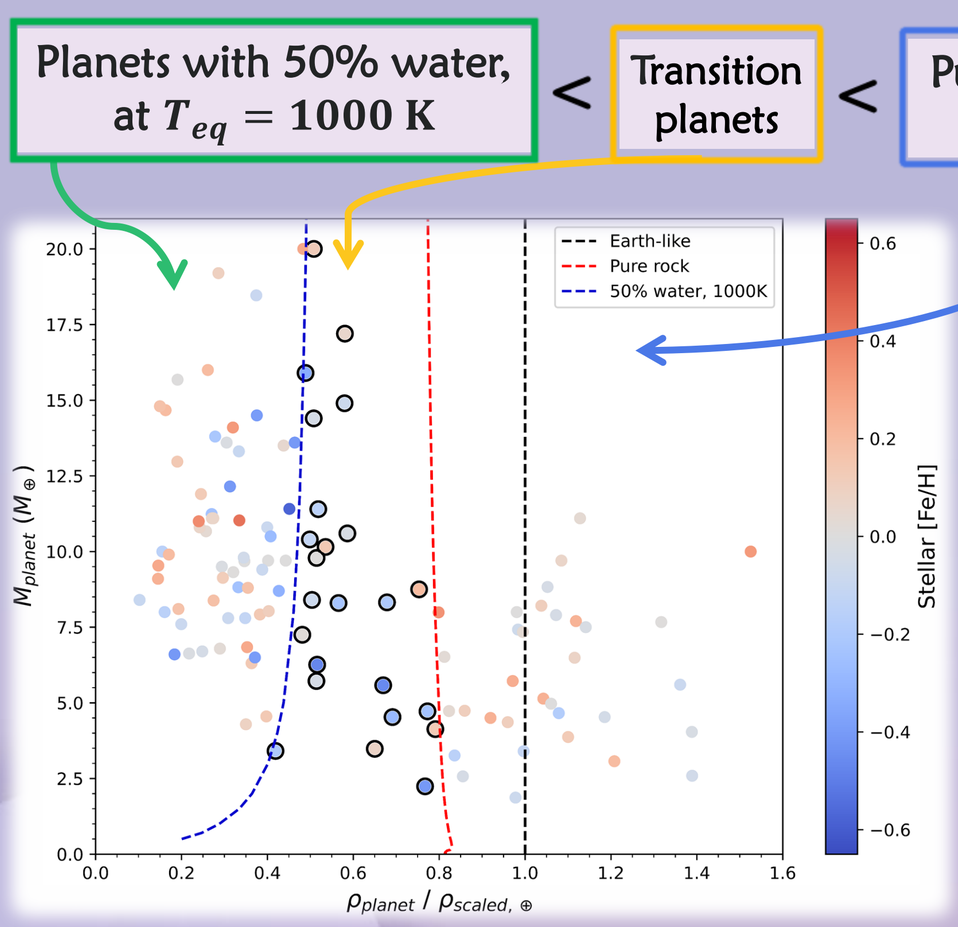
Planet formation models predict steam worlds to originate from water-rich sub-Neptunes. Could these planets possibly be a **transition** between super-Earths and sub-Neptunes?



How to choose them?

- M < 20 M⊕ & R < 4 R⊕
- Density separation: mass-radius relations from planet interior models

Planets with 50% water, at $T_{eq} = 1000$ K < Transition planets < Pure silicate planets



The R_{planet} - $[Fe/H]_{star}$ correlation

- We confirm the existence of a **strong correlation** for the **sub-Neptune** population, and a lack of it for the rest of the planets.
- However, there is a **weaker correlation for super-Earths** and **no correlation** at all for the **transition planets**.

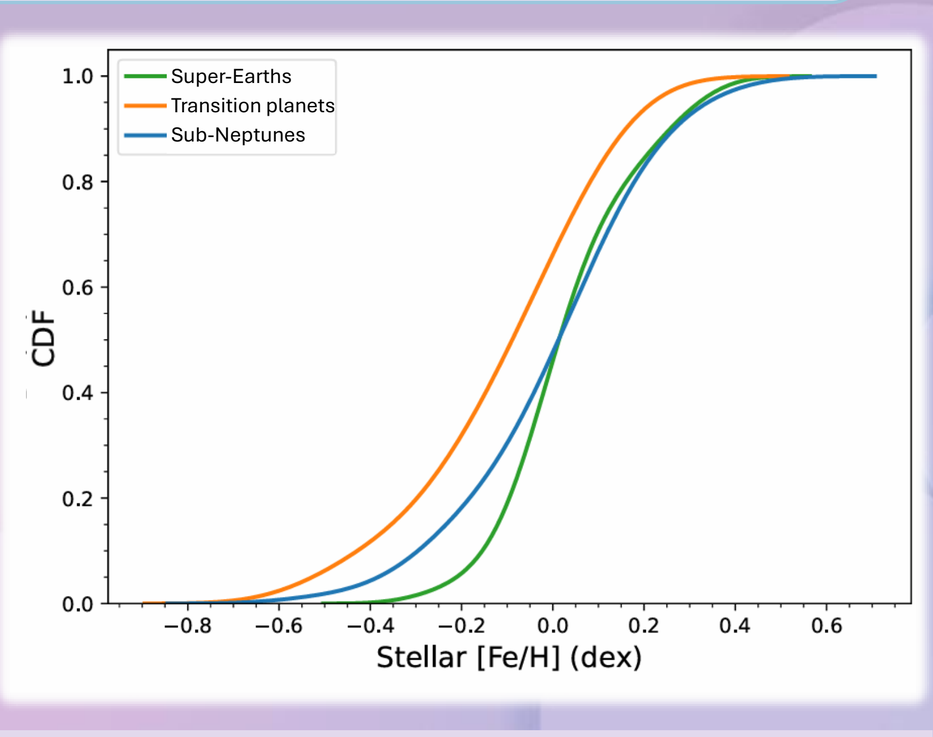
Differences in the [Fe/H] distribution

✔ super-Earths and sub-Neptunes hosts: same [Fe/H] distribution
✘ transition planets hosts: different [Fe/H] distribution

→ Anderson-Darling tests show the difference in [Fe/H] distribution between transition planets and the populations of super-Earths and sub-Neptunes is statistically significant (p-value < 0,05).

Conclusions

- Smaller sub-Neptunes orbit stars with **different properties** than larger sub-Neptunes, and reveal **different composition** from their larger counterparts → possible presence of steam worlds
- Steam worlds appear to be a **separate population**, and not just a scaled-down versions of larger sub-Neptunes.
- The loss of sub-Neptunes' atmosphere is not enough to explain the existence of these planets → a different formation mechanism?
- Further studies are needed to understand the origin of these planets.



REFERENCES

Chen et al. 2025; Egger et al. 2025; Fulton et al. 2017; Fulton & Petigura 2018; Gupta & Schlichting (2020); Mordasini, Alibert, et al. 2009; Otegi et al. 2020; Owen & Murray-Clay 2018; Owen & Wu 2013; Parc et al. 2024; Petigura et al. 2018, 2022; Venturini et al. 2020; Zeng et al. 2019.

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